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VI. *Directions for using the common Micrometer, taken from a Paper in the late Dr. Bradley's Hand-writing; communicated by Nevil Maskelyne, Astronomer Royal, and F. R. S.*

Read Feb. 20, 1772. **M**ICROMETERS, as first contrived, being only adapted to the measuring small angles, as the diameters of the Sun and Moon, or other planets, and taking the distance of such objects as appeared within the aperture of the telescope at the same time, were not of so general use as those which are contrived not only to answer the ends that the first inventors aimed at, but likewise, to take the difference of right ascension and declination of such objects as are farther asunder than the telescope will take in at once, but which pass through the aperture of it at different times. Mr. Cassini first made use of threads intersecting one another at half right angles for determining the difference of right ascensions and declinations of objects near the same parallel; and this apparatus being simple and easily procured is of very great use to such as are not provided with a micrometer made according to the late improvements. But, where such a one is at hand, that method however curious need not be made use of, the micrometer

meter serving for the same purpose with greater exactness. It was for this reason indeed that the late alteration in the form of the micrometer was made, they being before not so convenient for making such sort of observations, both hairs being usually moveable, and no provision being made for setting the hairs parallel to the diurnal motion of the objects to be observed; both which inconveniencies are avoided in the present micrometers.

The micrometer, as now contrived, is not only of use in measuring small angles or distances between such objects as appear within the aperture of the telescope at the same time, but likewise in taking the difference of right ascension and declination between stars and planets, &c. which in their apparent diurnal motion follow one another through the telescope if kept in the same situation. In making the first kind of observations, turn the short tube which carries the eye glass and micrometer, &c. till the cross thread (or that which cuts the parallel threads at right angles) lies parallel to a line passing through the objects whose distance is to be measured, and then by raising or depressing the telescope by help of the stand bring the objects to appear upon or near the cross thread, and one of them just to touch the first parallel thread: then turn the index of the micrometer till the moveable thread touches the other object, and the number of revolutions and parts of a revolution shewn by the index, turned into minutes and seconds by the table made as hereafter directed, will be the apparent angular distance of those objects. It is here supposed, that the threads exactly close, so as to touch each other
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when the index stands at the beginning of the divisions: for, if they do not, there must be an allowance made in every observation; to avoid which, it is always best to adjust the threads to the beginning of the divisions when they are first put on; for which purpose the holes in the little plate which carries the moveable thread are made oblong to give room to move it as occasion requires, before it is pinched hard by the small screws which fasten it to the moveable arm, through which the long screw passes. The other parallel thread, which I call the fixed one, must be first adjusted by setting its edge exactly over the two marks made on each side the short diameter of the aperture in the broad plates, and the cross thread must be likewise set to agree with the strokes made on each side the longest diameter, and then the intersection of the cross thread and the first parallel one will be the center of the motion given to the outer plate of the micrometer (to which the great screw index and threads are fastened) by the worm, by turning of which the first parallel thread may easily be made to lie parallel to the apparent motion of any object in order to take the difference of declination and right ascension from any other that follows through the aperture of the telescope.

This contrivance is of very great use to make a star, &c. move true along the first parallel thread, which is absolutely necessary in order to take the true difference of right ascension and declination between it and any other that follows. Without this contrivance it is very difficult to make a star move exactly upon the thread, and it can only be done by repeated

peated trials, which may sometimes take up a great deal of time.

If therefore a star is made to move on the parallel thread just at the cross, and (the telescope continuing fixt in the same position) it is afterwards near its going out of the aperture found not to be upon the thread, that must then be brought to the star by the help of the worm, and then the thread will lie parallel to the diurnal motion of the star in that part of the heavens, and consequently the cross thread will represent a meridian, and the others parallels of declinations, and the difference of time between the passage of the star at the cross wire (which was made to move along the thread), and the transit of any other star, &c. over the cross thread which represents a meridian, turned into degrees and minutes, will give the difference of right ascension. And, if the moveable parallel thread be brought, by turning the index, to touch the other star about the time of its passage over the cross thread, then the number of revolutions and parts shewn by the index (turned into minutes and seconds of a degree by the table) will be the difference of declination between the two stars. If the star is made to pass along the fixed thread so as to seem perfectly bisected, there must be an allowance made for the semidiameter of the thread or wire, because I suppose the index to be adjusted as before to the inner edges of the wires; but it may, if it is found convenient, be adjusted to the middle of the threads, or else correction may be made in the observed distance.

In taking any angle, it is convenient that each of the parallel threads be about the same distance from

the middle of the aperture of the eye-glass; and for this reason the whole micrometer is contrived to slide to and fro, as the case requires. The same motion is also of use in taking the difference of right ascension and declination, by sliding the first parallel thread (on which the preceding star is brought to move) towards one side of the eye-glass; for by that means a greater angle may be taken in between the parallel threads, if need be. And it must always be remembered that the moveable parallel thread should be set either north or south of the other, according as the following star is expected to be really south or north of the preceding.

In making an observation, either the inner or the outer edges or the middle of the wires may be brought to touch the objects; but then, it must be remembered to allow something for the thickness of the wire, in case the observation be not made from that part to which the index is adjusted. In observing the diameters of the sun moon or planets, it may perhaps be most convenient to make use of the outer edges of the threads, because they will appear most distinct when quite within the limb of the planet; &c. but if there should be any sensible inflection of the rays of light in passing by the wires, this would be best avoided by using the inner edge of one wire and the outer edge of the other. And in taking the distance or difference of declination between two stars, &c. the middle of the threads may perhaps be most convenient: but, however the observation is made, due correction must be allowed for the thickness of the wire, if requisite.

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The difference of declination of two stars, &c. may be observed with great exactness, because the motion of the stars is parallel to the threads; but in taking any other distance, the motion of the stars being oblique to them is a great impediment, because if one star be brought to one thread before the eye can be directed so as to judge how the other thread agrees to the other star, the former must be somewhat removed from its thread, so that in this sort of observations the best way of judging when the threads are at the proper distance is by frequently moving the eye backwards and forwards from one to the other: this method must chiefly be made use of when the distance of the objects is pretty large, and the motion or rowling of the eye great.

The micrometer is so contrived that it may be applied to telescopes of different lengths; but then, there must be a table for each telescope, by which the revolutions of the screw may be turned into minutes and seconds of a degree. In order to this it is necessary that the threads of the micrometer should be placed exactly in the common focus of the object-glass and eye-glass, that is, where the images of objects seen through the telescope are distinctly formed. The readiest way of doing this is, first to slide the micrometer into the grooves fixt to the short brass tube, which carries the whole apparatus of eye-glass, &c. and then to draw the eye-glass out by means of its sliding work, till the threads of the micrometer are in its focus, which is known by their appearing most distinct, &c. Then thrust the short tube before-mentioned into its proper place, as far

as the shoulders of the brass work will admit, and place the object glass in its cell, and looking through the telescope at some very distant object slide the wooden tube in or out till you make the object appear most distinct, or till it has the least motion upon the threads when the eye is moved to and fro; for then the threads of the micrometer will be in the common focus of both glasses, and that will be the proper distance that the object-glass ought always to be at from the threads; and there should be made some mark or ketch in the wooden tube in order to set it always at the same distance.

The proper distance of the threads from the object-glass being thus settled, the table for turning the revolutions, &c. of the screw into angles or minutes and seconds of a degree may be made several ways; but as good and easy a method as any is carefully to measure how many inches and parts of an inch the object-glass is distant from the threads, and with the same scale to find also how many inches and parts of an inch an hundred, &c. revolutions or threads of the screw of the micrometer are equal to: then, making the first distance radius, the last will be the sine or tangent of an angle answering to 100 revolutions. And having the angle answering to 100 revolutions, the angle for any other number will be easily known and set down in the table, as also the parts of a revolution; for in small angles, such as can be observed with the micrometer, their sines tangents or cords are nearly in the same proportion with the angles themselves. The distance before-mentioned (to be used as radius) ought strictly to be taken from the threads to a
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point within the object glass about one third of its thickness from that surface which is towards the wires, if the glass be, as usual, equally convex on both sides; but if the focus of the object-glass is pretty long and its thickness not great, the error that can arise by measuring from any part of the object-glass will become insensible as to the alteration in the angle.

The table for the micrometer may likewise be made by setting up two marks at a distance on the ground, and observing with the micrometer the revolutions, &c. which they subtend when seen through the telescope, and then computing the angles those objects subtend at the object-glass, by measuring their distance from each other and from the object-glass. The like may also be done by opening the threads to any number of revolutions, and then making a star move exactly upon the perpendicular thread, and noting the time it is passing from one parallel thread to the other; for that time turned into minutes and seconds of a degree, by allowing for the star's declination and going of the clock, &c. will be the angle answering to the number of revolutions; from which the whole table may be made. This method perhaps might be most advantageously practised in stars near the pole, where the apparent motion being slow a second in time will answer to a much smaller angle than towards the equator. But I believe, upon trial, the first method will be found most easy and practicable, especially if the scale made use of be well divided.